sPHENIX Calorimeters

Hanpu Jiang for sPHENIX Collaboration

Aug 2nd, 2023
A prototype of the sPHENIX calorimeter system was tested at the Fermilab Test Beam Facility in 2016. (arXiv:1704.01461)
sPHENIX Calorimeters Jet Program

Jet Energy Resolution

JER and JES:
- Jets from clusters of calorimeter towers.
- Event-by-event underlying event subtraction.
- EM-scale jets, no flow subtraction.

Jet-to-photon momentum balance

$$x_{j\gamma} = \frac{p_T^{\text{jet}}}{p_T^{\gamma}}$$

$$x_{j\gamma}$$ distribution for Au+Au shift towards lower value due to jet quenching.

A direct measure of the jet energy loss.
Electromagnetic Calorimeter

- Tungsten-scintillating fiber sampling calorimeter.
- Locate outside TPC & TPOT.
- Cover full azimuthal angle $2\pi$ and $|\eta| < 1.1$.
- 64 sectors total: 32 azimuthal x 2 longitudinal.
- Interaction length: $0.83\ \lambda_{int}$. Radiation length: $20.1\ X_0$
- Moliere radius $R_M \sim 2.3$ cm in EMCal.
- Energy resolution: $\sigma_E/E = 5\% \oplus 16\%/\sqrt{E}$

Installed Nov. 2022
Electromagnetic Calorimeter

- Each sector will subtend $11.2^\circ$ in $\phi$, 1.1 units in $\eta$. Two sectors cover the $\eta$ acceptance from -1.1 to 1.1.

- A sector contains 96 modules. Each module is an absorber block that is divided into 2x2 towers.

- Each tower has a light guide at the inner surface and is read out with 4 silicon photomultipliers (SiPMs). One pre-amp board sums the signal from 4 SiPMs together to read out.

- 96 modules in a sector: 4 azimuthal x 24 longitudinal, that $8 \times 48 = 384$ towers in a sector. Towers tilts in $\eta$ to point to center, and slightly in $\phi$.

- There are totally 256 azimuthal x 96 longitudinal = 24576 towers, with each tower covers $\Delta \eta \times \Delta \phi = 0.025 \times 0.025$
Hadronic Calorimeters

- First mid-rapidity hadronic calorimeter at RHIC.
- Al (inner) and steel (outer) absorber plates, scintillating tiles with embedded WLS fibers.
- Locate outside the EMCal, with the magnet intervening in between.
- Covers $|\eta| < 1.1$ and full azimuthal angle $2\pi$ with 32 sectors (for both i&oHCal).
- Overall HCal energy resolution: $\sigma_E/E \sim 14\% \oplus 81%/\sqrt{E}$ for hadrons, $\sigma_E/E \sim 11\% \oplus 31%/\sqrt{E}$ for electrons.
- Total $5 \lambda_{int}$ for both calorimeters combined.

Installed May & June 2022
Hadronic Calorimeters

- One oHCal sector has 10 scintillator slots. One iHCal sector has 8 scintillator slots.
- Each slot is filled with 24 tiles along $z$. Tiles have different sizes and shapes to be projective in $\eta$.
- Tower is the collection of tiles. 5 tiles in oHCal, and 4 tiles in iHCal. One sector has 48 towers that separated into two lines.
- Total 1536 towers. Each tower covers $\Delta \eta \times \Delta \phi = 0.1 \times 0.1$. Each HCal tower corresponds to 16 EMCal towers.
- The tiles are tilted in $\phi$. oHCal tilts 12° relative to radius, iHCal tilts 32° in opposite direction. Particles from center will pass at least 4 tiles.
- A SiPM is installed on each tile. All 5 or 4 tiles’ SiPMs in the same one tower are read out together.
Monitoring & Calibration

Calorimeter monitoring methods:

- Detector status information is monitored through slow control cables, such as bias voltage and temperature.
- Online monitoring is set up for shifter, basing on channels’ running mean packet status, waveform and so on.
- Test pulse runs and LED runs are taken regularly to monitoring the status of HCal.

Calorimeter relative calibration:

- MIP calibration with cosmic muon. (Pre-installation preliminary calibration done separately for EMCal and HCal)
- Ongoing tower slope method for EMCal.

Ongoing absolute calibration:

- $\pi^0$ tower-by-tower calibration and get overall energy scale for EMCal.
- Correlation between cosmic muon MIP and Geant4 simulation to get the electromagnetic energy scale for HCal.
The correlation between the total energy in the o/iHCAl and total charge in the minimum bias detector (MBD) in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

- 64 channels each side of 3cm thick quartz radiator on mesh dynode PMT.
- Covers $3.51 < |\eta| < 4.61$.
- Timing resolution: 120 ps.
The di-photon mass distribution in units of ADC. $\pi^0$ peak around 90-100 ADC.
Overall tower’s MIP cosmic energy spectrum (with direction perpendicular to radius)
Summary:

- sPHENIX calorimeters are both functional and have preliminary calibration data.
- More ongoing calibrations making good progress.
- The calorimeters commissioning verify that calorimeters are ready for physics data taking.
- First-year jet analysis basing on calorimeters are underway.

Related talks and poster:

- *sPHENIX Overview* - Ejiro Umaka
- *Progress Toward Jet Physics Measurements in sPHENIX* - Anthony Hodges
- *Commissioning Status of the sPHENIX Electromagnetic Calorimeter (POSTER)* - Abraham Holtermann, Marzia Rosati
Thank you!
Backup
EMCal Tower Slope Method

EMCal tower’s energy distribution

+5% Calib shift input

sPHENIX Simple MC

Tower Slope Fit
EMCal Resolution

Design and Beam Test Results for the 2D Projective sPHENIX Electromagnetic Calorimeter Prototype (arXiv:2003.13685)
HCal Resolution

Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes (arXiv:1704.01461)

Wednesday, Aug 2nd, 2023
sPHENIX Calorimeters – Hanpu Jiang
Hadron Resolution

Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes (arXiv:1704.01461)